DOE-EM/GJ1250-2006

299-W18-72 (A7555)
Log Data Report

Borehole Information:

Borehole: 299-W-18-72 (A7555)		**Site:** 216-Z-12 Crib			
Coordinates (WA State Plane)		**GWL (ft)**[1]: None		**GWL Date:** 11/28/05	
North	**East**	**Drill Date**	**TOC**[2] **Elevation**	**Total Depth (ft)**	**Type**
135437.805	566362.123	03/67	N/A[3]	26	Cable

Casing Information:

Casing Type	Stickup (ft)	Outer Diameter (in.)	Inside Diameter (in.)	Thickness (in.)	Top (ft)	Bottom (ft)
Welded steel	1.65	6 5/8	6	5/16	1.65	26

Borehole Notes:

Casing diameter and casing stickup measurements were acquired by the logging engineer using a caliper and steel tape. Measurements were rounded to the nearest 1/16 in. All logging measurements are referenced to the top of casing.

Kasper (1982) reports six shallow wells (70 through 75) were drilled in the 216-Z-12 crib in 1967 to determine if discharged waste was being dispersed over the entire bottom area of the crib. "The wells were drilled until alpha contamination was encountered, or a few feet below where it could be expected to be encountered." (quote from Crawley, 1967; reference unavailable). Using a portable radiation survey instrument ("poppy"), no activity was detected in well 72. This well is located along the distribution pipe in the center of the crib, at approximately 17 ft in depth (probably from ground surface), near the beginning of the southern two-thirds of the crib. It was concluded that the flow of the waste to the crib was insufficient to distribute the liquid over the entire crib bottom. As a result, in July 1968, a diversion pipe was installed in the crib, bypassing the first 100 ft of the distributor pipe. From July 1968 to May 1973, when the crib was retired, waste was discharged only to the southern two-thirds of the crib (Kasper 1982).

Logging Equipment Information:

Logging System:	Gamma 1E		**Type:** SGLS (70%) 34TP40587A
Effective Calibration Date:	03/04/05	**Calibration Reference:**	DOE/EM-GJ864-2005
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Spectral Gamma Logging System (SGLS) Log Run Information:

Log Run	**1**	**2 - Repeat**			
Date	11/29/05	11/29/05			
Logging Engineer	Spatz	Spatz			
Start Depth (ft)	22.0	22.0			

Log Run	1	2 - Repeat			
Finish Depth (ft)	2.0	22.0			
Count Time (sec)	200	1000			
Live/Real	R	R			
Shield (Y/N)	N	N			
MSA Interval (ft)	1.0	1.0			
ft/min	N/A	N/A			
Pre-Verification	AE135CAB	AE135CAB			
Start File	AE135000	AE135021			
Finish File	AE135020	AE135021			
Post-Verification	AE136CAA	AE136CAA			
Depth Return Error (in.)	-1	0			
Comments	No fine-gain adjustment.	No fine-gain adjustment. Count time 1000 s			

Logging Operation Notes:

Logging was conducted November 29, 2005 using SGLS logging system Gamma 1E. Pre- and post-survey verification measurements for the SGLS employed the Amersham KUT (^{40}K, ^{238}U, and ^{232}Th) verifier with serial number 118. An additional measurement was acquired at the depth of highest gamma activity at 22 ft at enhanced counting time (1000 seconds) to further investigate energy peaks observed in the original log run (log run 1). All measurements were performed with a centralizer installed on the sonde. The top of casing is the reference depth for log data.

Analysis Notes:

Analyst:	Henwood	Date:	01/31/06	Reference:	GJO-HGLP 1.6.3, Rev. 0

SGLS pre-run and post-run verification spectra were collected at the beginning and end of the day. All of the verification spectra were within the acceptance criteria. Examinations of spectra indicate that the detector functioned normally during logging, and the spectra are accepted.

Log spectra were processed in batch mode using APTEC SUPERVISOR to identify individual energy peaks and determine count rates. Verification spectra were used to determine the energy and resolution calibration for processing the data using APTEC SUPERVISOR. Concentrations were calculated in EXCEL (source files G1Emar05.xls). Log data were corrected for a casing thickness of 5/16-in.

Results and Interpretations:

Elevated gamma activity is observed at 21 and 22 ft near the bottom of the borehole. ^{237}Np, ^{241}Am, ^{239}Pu, and ^{241}Pu are identified. In a spectrum at 22 ft with a 1000 second counting time, additional gamma lines are identified that may be attributed to ^{56}Mn and ^{22}Na. Neutron capture gamma lines associated with H, Fe, and Si are also identified. All the counts acquired in the 662 keV energy peak line cannot be attributed to any single radionuclide. The table below indicates the gamma lines of man-made radionuclides identified in the spectrum at 22 ft that were acquired over a 1000 second time interval. The SGLS cannot resolve energy peaks at less than approximately 3 keV so that more than one radionuclide can contribute to an energy peak causing interferences. The table is intended as a worksheet for the analyst that contains the most probable gamma lines expected, considering the dominant radionuclides (i.e., ^{241}Am, ^{239}Pu, ^{237}Np) and knowledge of the waste stream. The table should not be considered to contain all the gamma lines that are possible.

Radionuclides are selected for assay based on comparisons of the highest gamma ray yield of an individual gamma line with the fewest potential interferences. For example, numerous gamma lines associated with decay of ^{241}Am were observed in the spectra. Energy peaks with the highest yields that are at least partially attributed to ^{241}Am were detected at approximately 208.01, 619.01, 662.40, and 722.01 keV (see ^{241}Am Energy Peak Comparison Plot). The plot suggests interfering gamma rays, where assays for ^{241}Am at 662.40 and 208.01 keV are clearly skewed relative to the 619.01 and 722.01 energy peaks. As can be determined from the table, the 662 keV peak could be influenced to some degree by gamma rays from ^{239}Pu or ^{137}Cs, the 619.01 keV peak from ^{239}Pu, and the 208.00 keV peak from ^{237}U. Thus, the 722.01 energy peak appears to have less potential influence and highest yield and was selected to best represent the concentration of ^{241}Am. Note: The possible influences to the 722.01 energy peak from ^{154}Eu and ^{208}Tl were ruled out as not likely, or insignificant, as the higher yielding ^{154}Eu peak at 1274 keV did not match the assay at 722.01 keV and could be attributed to another radionuclide, and ^{208}Tl (used for assay of ^{232}Th) at the higher yielding 2615 keV was determined to be consistent with background ^{232}Th. The final concentrations for ^{241}Am, based on the 722.01 keV energy peak, were determined to be 1,367,266 and 207,123 pCi/g, at 21 and 22 ft, respectively.

Borehole 299-W18-72 Energy Peaks (1000 sec count time)

Approx. Peak/Library Name	Am-241 Energy/yield % 1x10^{-5}	Pu-239 Energy/yield % 1x10^{-6}	Pa-233 Energy/yield %	U-237 Energy/yield %	Other possibilities
99/^{241}Am	98.97/2030	98.78/1220			Many others
103/^{241}Am	102.98/1950	103.06/230	103.97/0.87	102.98/0.0064	Many others
125/^{241}Am	125.30/408	123.22/0.002 123.62/19.7 124.51/61.3			
129/^{239}Pu		129.296/6310			
161/^{239}Pu	161.15/0.15	160.19/6.2 161.45/123			^{240}Pu 160.30/0.0004
165/^{241}Am	164.69/6.67 165.81/2.32			164.61/1.85	
196/^{239}Pu		195.679/107 196.87/3.7			^{237}Np 194.95/0.184
204/^{239}Pu	204.06/0.29	203.55/569			
208/^{241}Am	208.01/79.1			208.00/21.14	
312/^{233}Pa		311.78/25.8	***312.17/38.6***		
322/^{239}Pu	322.52/15.18	320.862/54.2 323.84/53.9			
333/^{239}Pu	332.35/14.90	332.84/494		332.36/1.19	
336/^{241}Am	335.37/49.6	336.113/112		337.7/0.0089	
341/^{239}Pu	340.56/0.43	341.506/66.2	340.81/4.47	340.45/0.0016	
345/^{239}Pu		***345.013/556***			
368/^{241}Am	368.65/21.7	367.073/89 368.55/88		368.59/0.040	
375/^{239}Pu	376.65/13.83	375.054/1554	375.45/0.679		
380/^{239}Pu		380.191/305			
383/^{241}Am	383.81/2.82	382.75/259			
393/^{239}Pu		392.53/205 393.14/348			
415/^{239}Pu	415.88/0.31	413.713/1466	415.76/1.74		
423/^{239}Pu		422.598/122			
426/^{241}Am	426.47/2.46	426.68/23.3			
451/^{239}Pu	452.6/0.24	451.481/189			
619/^{241}Am	619.01/5.94	618.28/2.04 619.21/1.21			
652/^{241}Am	653.02/3.77	652.05/6.6			
662/^{241}Am	662.40/36.4	658.86/9.7 664.58/1.66			^{137}Cs 661.66/85
689/^{241}Am	688.72/3.2	688.1/0.1			
722/^{241}Am	***722.01/19.6***				^{154}Eu 722.30/20 ^{208}Tl 722.04/0.201
737/^{241}Am	737.34/0.80				

Approx. Peak/Library Name	Am-241 Energy/yield % $1x10^{-5}$	Pu-239 Energy/yield % $1x10^{-6}$	Pa-233 Energy/yield %	U-237 Energy/yield %	Other possibilities
756/^{241}Am	755.90/0.76	756.4/0.67			^{154}Eu 756.80/4.57
766/^{238}Pu					^{238}Pu 766.3/ $2.2x10^{-5}$
769/^{239}Pu	770.57/0.47	769.15/5.1 769.37/6.8			
846/^{56}Mn	847.4/0.03				^{56}Mn (n,g) ^{56}Mn 846.75/98.87
1274/^{22}Na					^{22}Na (α,n) 1274.53/99.94 ^{154}Eu 1274.436/35.19
1725/Fe					Fe capture/1725.29
1780/^{28}Al					^{27}Al (n,g) ^{28}Al 1778.85/100
1809/^{56}Mn					^{56}Mn (n,g) 1810.72/27.12
2223/H					H capture/2223.25
2235/Si					Si capture/ 2235.23

Energy peaks in bold italics are suggested for assays after subtracting interfering counts where appropriate.

The ^{241}Am concentrations derived from the 208.01 keV gamma line also appear to be over estimated. A 208.000 keV gamma line that results from the decay of ^{237}U, interferes with the 208.01 keV gamma line caused by the decay of ^{241}Am. The presence of ^{237}U with a half life of 6.7 days indicates that ^{241}Pu with a half life of 14.4 years is present. After subtracting the counts from the 208 keV peak attributed to ^{241}Am (based on the 722.01 keV peak) it is determined the concentration of ^{237}U is approximately 130 pCi/g. Because ^{237}U is the daughter of ^{241}Pu and is in equilibrium with its parent, this concentration reflects the concentration of ^{241}Pu.

An evaluation of ^{239}Pu peaks that was similar to the ^{241}Am analysis determined the 345.01 energy peak had no obvious interferences (see Table) and was used to calculate concentrations. The concentrations for ^{239}Pu at 21 and 22 ft were 1,436,919 and 106,360 pCi/g, respectively.

Weapons grade plutonium is generally considered to be in approximate proportions of 94% ^{239}Pu, 6% ^{240}Pu, and 0.005% ^{241}Pu. Using these proportions, ^{240}Pu could be expected to be on the order of 75,000 pCi/g at 22 ft. No direct assay of ^{240}Pu is possible.

^{237}Np as determined from a decay product (^{233}Pa at 312 keV) was detected at 21 and 22 ft at concentrations of approximately 3 and 24 pCi/g, respectively.

Evidence of a significant neutron flux is apparent from the spectra. Neutrons can be generated by interactions of alpha particles with light elements (α, n reactions) or, to a lesser degree, from spontaneous fission, primarily from even numbered Pu isotopes. Positive evidence of a neutron flux is shown in the spectra by a hydrogen capture gamma ray at 2223.25 keV. Less prominent capture peaks for Si (2235.23 keV) and Fe (1725.29) are also observed.

Other evidence of neutron reactions include ^{55}Mn (n,g) ^{56}Mn. An energy peak at 846.75 keV and corroborated by the 1810.72 keV energy peak may be the result of decay of ^{56}Mn (2.6 hr half life) to ^{56}Fe. Despite this short half-life, this decay will occur as long as manganese and sufficient neutron activity remains.

The reaction ^{27}Al (n,g) ^{28}Al may be creating a gamma ray at 1778.85 keV. Another possibility could be an α-interaction with ^{25}Mg.

Another reaction ^{19}F (α,n) ^{22}Na yields a gamma ray at 1274.53 keV and a positron at 511 keV. A 1274.44 keV gamma ray also occurs from the decay of ^{154}Eu. However, there are no corroborating peaks for the

^{154}Eu and the gamma ray is attributed to the fluorine reaction. As with the ^{56}Mn, the half-life of ^{22}Na is short (i.e., 2.6 years), but will continue to be produced as long as sufficient fluorine and neutron activity exist.

Counts acquired in the 662 keV energy peak from the spectrum collected for 1000 seconds were approximately 38 counts per second. Fourteen of these counts are attributed to contributions from the ^{241}Am gamma energy line at 662.40 keV. Possible interferences to the 662.40 energy peak can be caused by the ^{137m}Ba gamma ray at 661.62 keV that reflects ^{137}Cs, and because ^{239}Pu is in this waste stream, a 658.86 keV ^{239}Pu peak. However, the ^{239}Pu contribution is estimated at less than 1 cps. Two other reactions associated with ^{140}Ce could occur: $^{140}Ce\ (n,\alpha)\ ^{137}Cs$ and neutron capture by ^{140}Ce to produce a gamma ray at 662.00 keV. These reactions would appear to be unlikely because of a very low neutron capture cross-section and the need for an energetic (fast) neutron (neutrons from the (α,n) reaction are considered thermal (slow)). However, spontaneous fission of ^{240}Pu, for example, does cause fast neutrons to be emitted and cerium was known to be used as an alloy with Pu and could have significant concentrations. ^{137}Cs created from this (n,α) reaction would be different than ^{137}Cs typically observed as a fission product, as it would be created at a constant rate in this environment and would not appear to decay away. Subsequent measurements in this borehole over time could establish the decay rate. If the 662 keV peak predominantly represents ^{137}Cs, the concentration after subtracting the ^{241}Am influence, is estimated at 2 and 10 pCi/g at 21 and 22 ft, respectively.

These neutron reactions may be indicating waste forms. Potassium permanganate, cerium, fluorine, and aluminum are all mentioned in the literature as having uses in the processing and refinement of the Pu product in the Plutonium Finishing Plant. The existence of PuF_4 is virtually certain as fluorine has a large capture cross section and as a compound with Pu, the alpha particles would not have to travel far (it is estimated alpha particles will travel approximately 0.01mm in soil) to create the (α,n) reaction. The other elements referred to could be constituents in the steel casing or natural sediments rather than part of the waste stream.

As described in the "Borehole Notes" section, this borehole was not found to exhibit contamination when it was drilled in 1967. Current log data show significant contamination at the bottom of the borehole. It appears the waste currently detected was deposited after the diversion pipe was placed in use in July 1968 and before its termination in 1973. Therefore, the waste was likely created between 37 and 42 years ago. This time frame would mean that any ^{241}Am resulting from decay of ^{241}Pu has approximately reached equilibrium with its parent such that the concentration of the ^{241}Am should equal the concentration of ^{241}Pu. However, the assay for ^{241}Pu is orders of magnitude less than the ^{241}Am, suggesting a dominant portion of the ^{241}Am originated in a different waste stream than the Pu.

Westinghouse Hanford Company (WHC) logged this borehole in 1993 with the Radionuclide Logging System (RLS) to a depth of 19.2 ft from ground surface. WHC reported ^{137}Cs at an activity of 0.3 to 0.4 pCi/g. Additionally, it was stated: "However, the activity of the cesium observed is insufficient to account for the increase of the total gamma ray count rate. Further investigation of this region is recommended." Current logging with the SGLS apparently was 1-2 ft deeper and transuranics have been noted.

Some of the possibilities regarding neutron capture reactions in this report should not be considered final interpretations. Additional boreholes in the 216-Z cribs are scheduled to be logged and once these data have been recorded and analyzed more definitive conclusions may be drawn. It is recommended that Stoller be consulted before all the existing boreholes are decommissioned. It appears re-visiting some of the boreholes would be useful for data interpretation.

This borehole is scheduled for decommissioning. The casing may be activated and removing the casing from the ground (if that is the plan) could create exposure hazards at the surface.

List of Plots:

Am-241 Energy Peak Comparison
^{239}Pu Energy Peak Comparison
Man-Made Radionuclides
Natural Gamma Logs
Combination Plot (1 in. = 20 ft)
Combination Plot (1 in. = 5 ft)
Total Gamma and Dead Time

References

Kasper, R.B., 1982. *216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium,* RHO-ST-44, Rockwell International, Richland, Washington.

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[1] GWL – groundwater level
[2] TOC – top of casing
[3] N/A – not applicable

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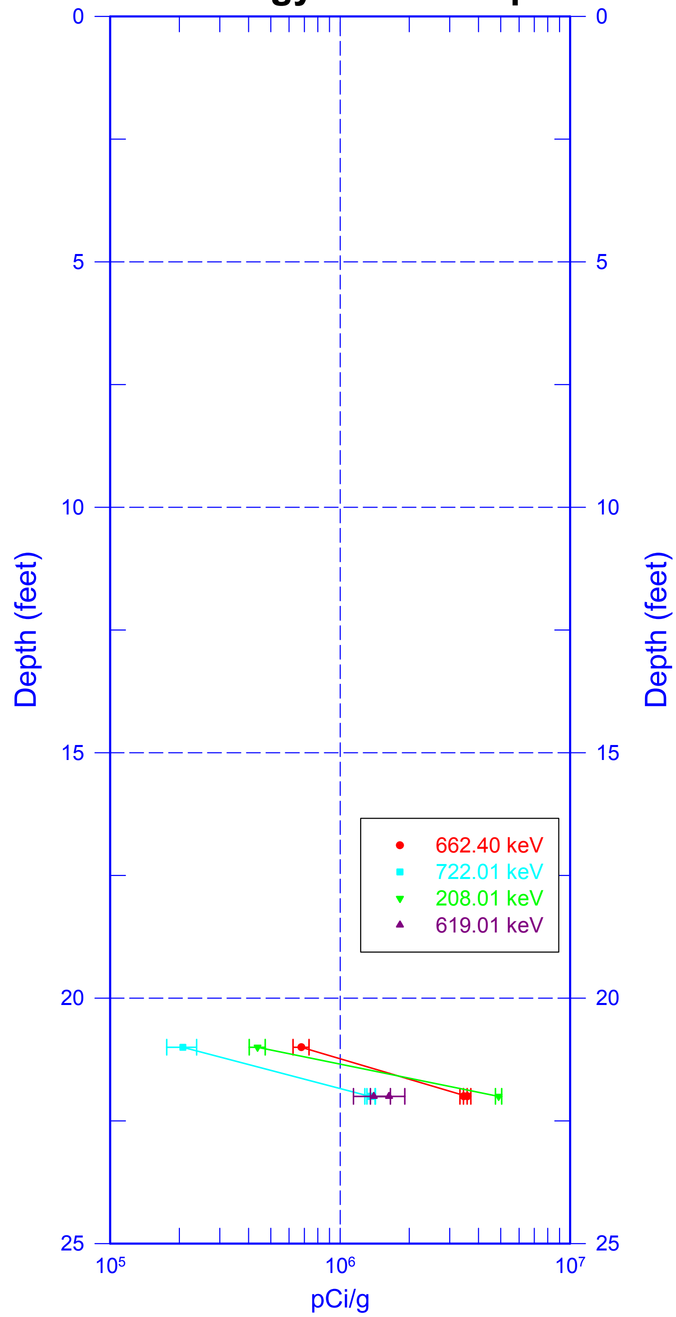
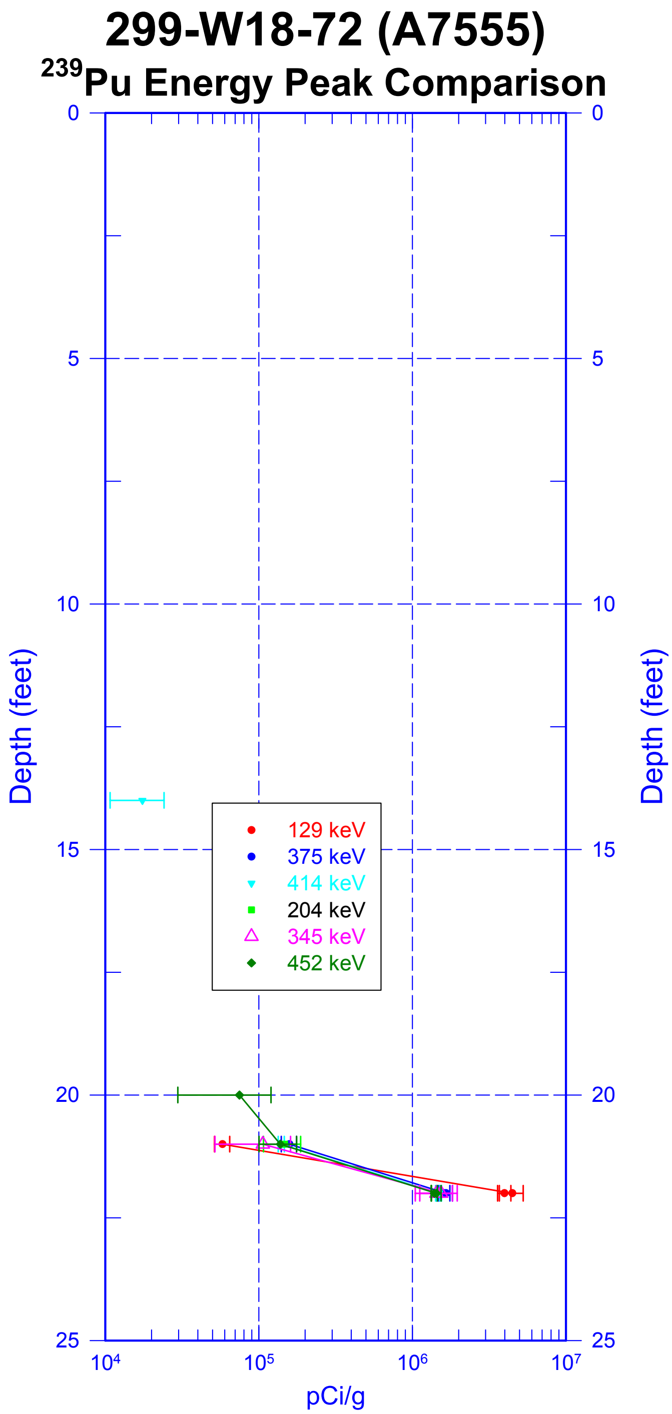
Am-241 Energy Peak Comparison



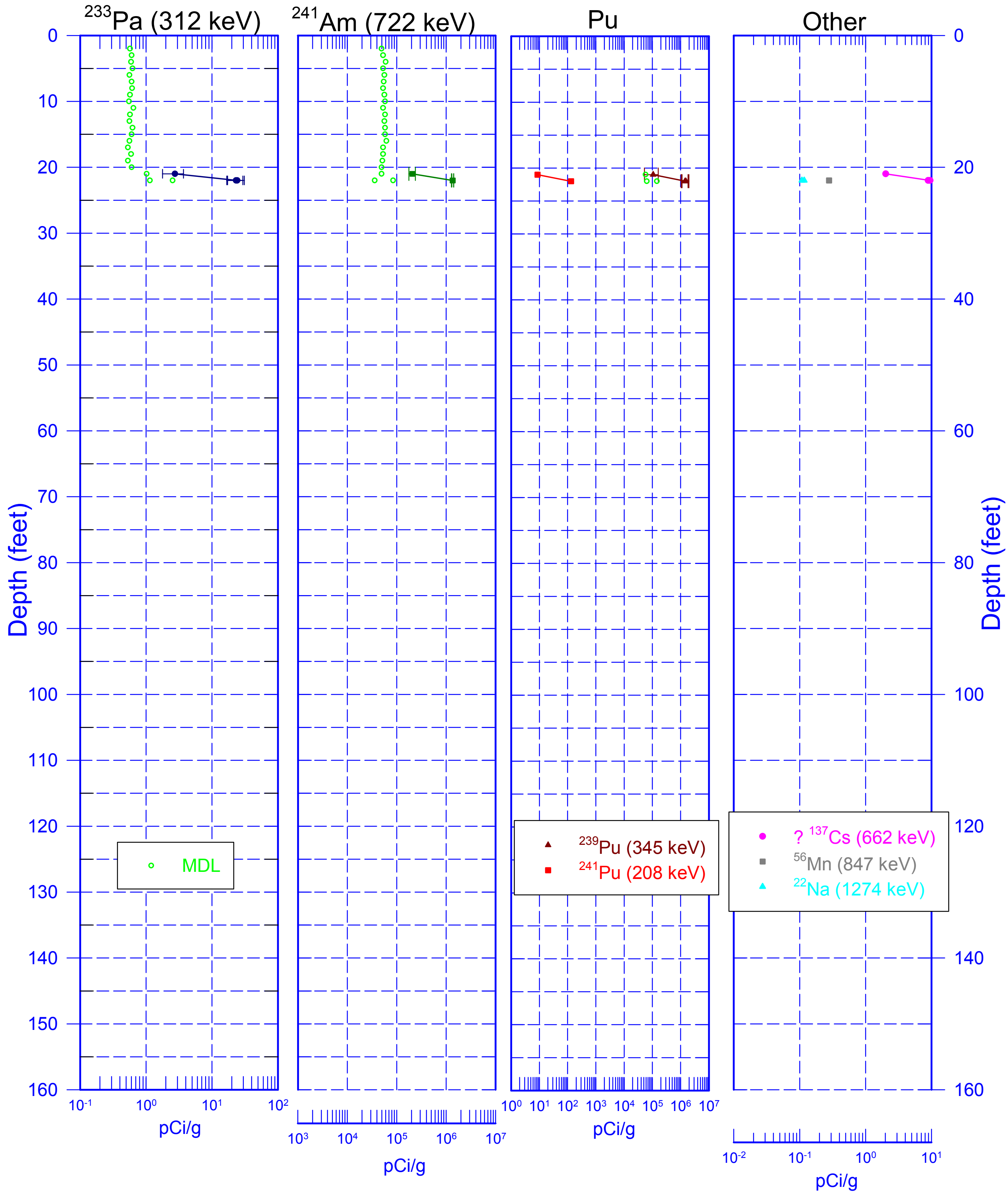
Zero Reference = Top of Casing



Zero Reference = Top of Casing

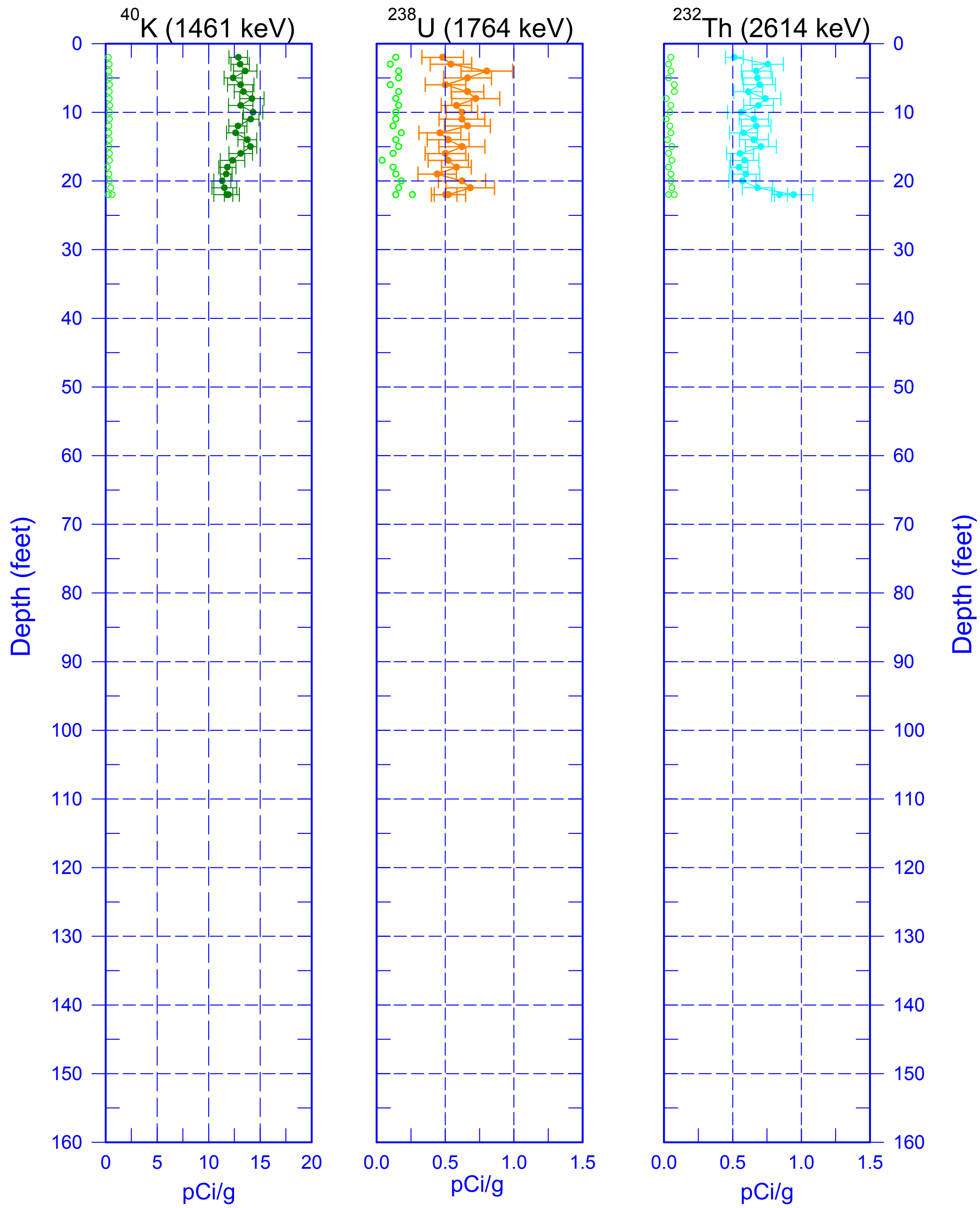
299-W18-72 (A7555)

Man-Made Radionuclides



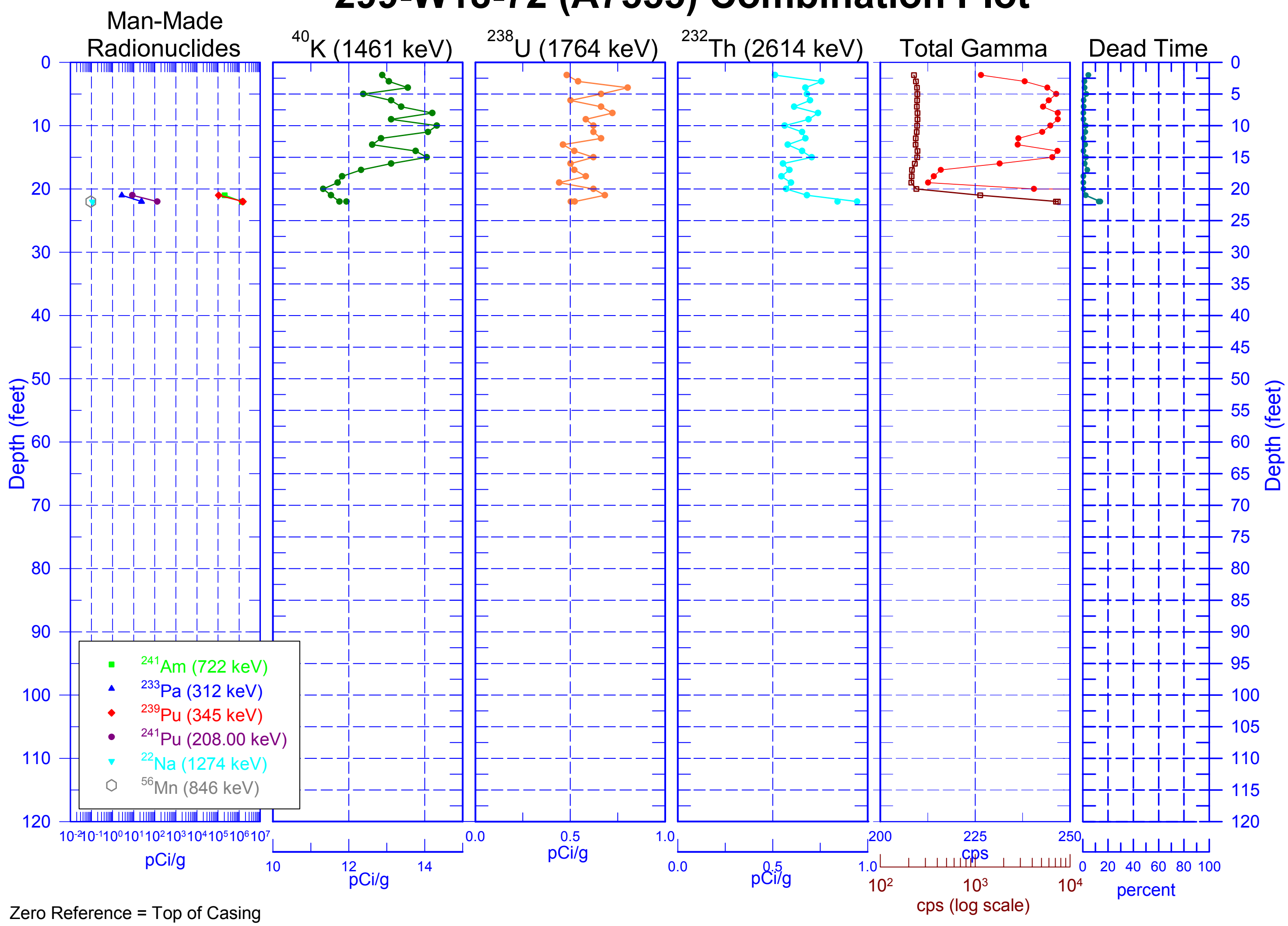
Zero Reference = Top of Casing

299-W18-72 (A7555)
Natural Gamma Logs



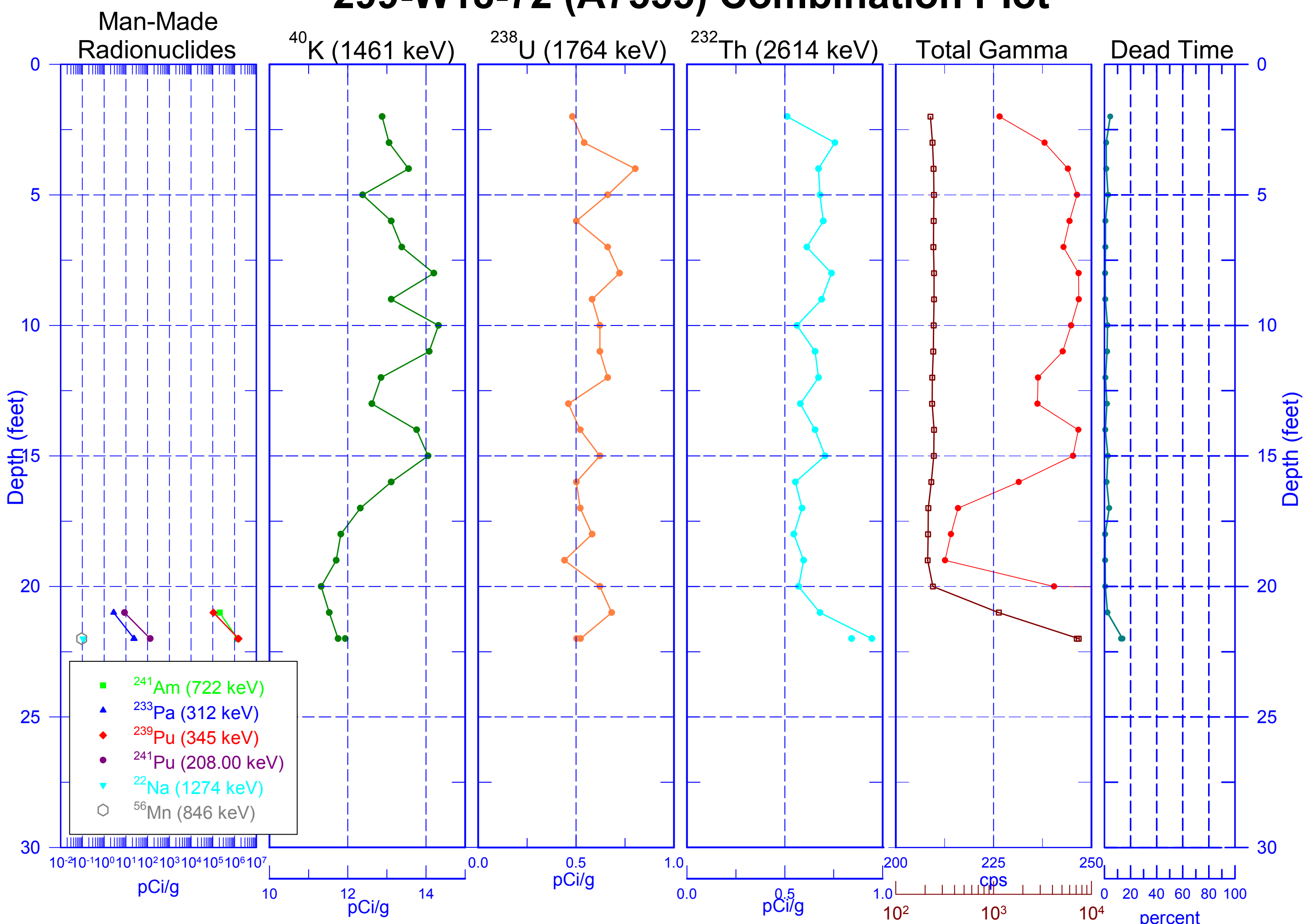
Zero Reference = Top of Casing

299-W18-72 (A7555) Combination Plot



Zero Reference = Top of Casing

299-W18-72 (A7555) Combination Plot



Zero Reference = Top of Casing

299-W18-72 (A7555)
Total Gamma & Dead Time